

The ATLAS hadronic tau trigger-performance and early running plans

Richard Brenner on the behalf of the ATLAS Tau Trigger Group

- Trigger motivation and description
- Use of tau trigger in searches for Higgs and exotica
- Trigger variables and performance
- Tau trigger menus
- Commissioning of tau trigger with first data

Tau trigger motivation and description

- Tau (trigger) is especially important for searches in the Higgs sector because the tau is the heaviest in the lepton family
 - Triggering taus will be difficult at LHC due to high rate and occupancy however a trigger will increase the discovery potential.
 - This presentation will focus on the trigger for hadronic tau decays while leptonic decay of taus will be triggered by the electron and muon triggers



Tau trigger in charged Higgs searches

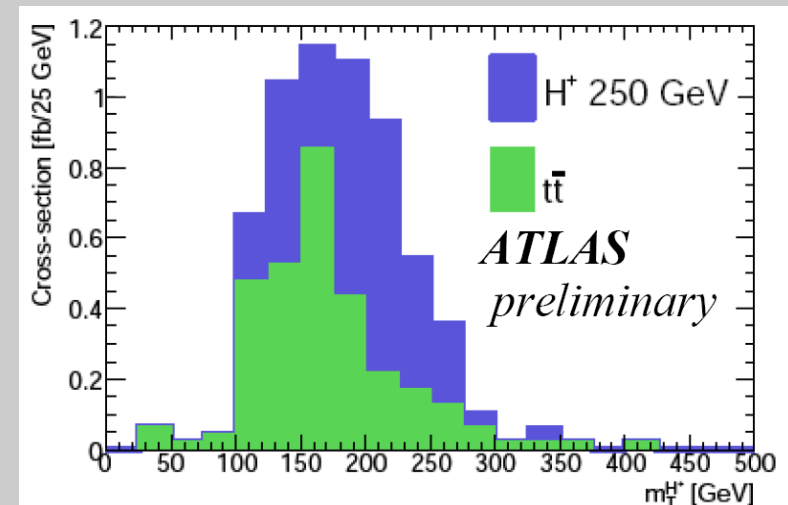
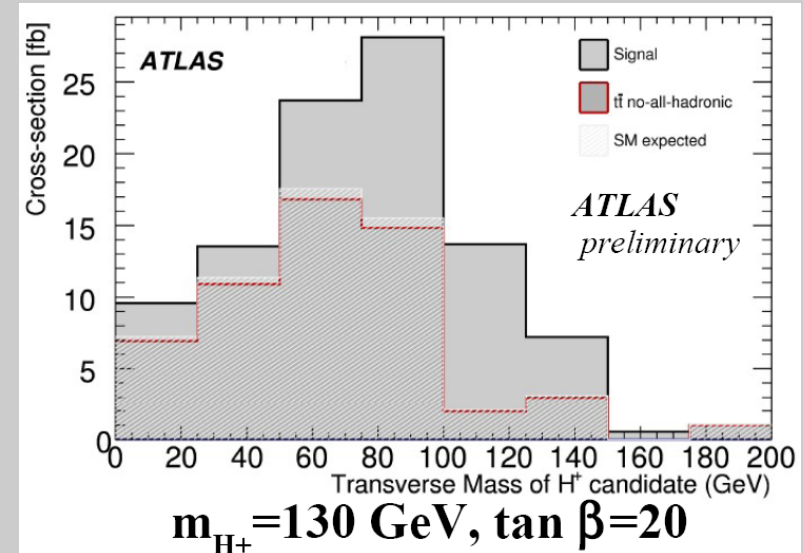
- Charged Higgs (*main customer for the tau trigger?*)

→ Light mass channel

$t\bar{t}(\text{bar}) \rightarrow bHbW \rightarrow$
 $\boxed{b} \boxed{\tau(\text{had})\nu} \boxed{bqq}$

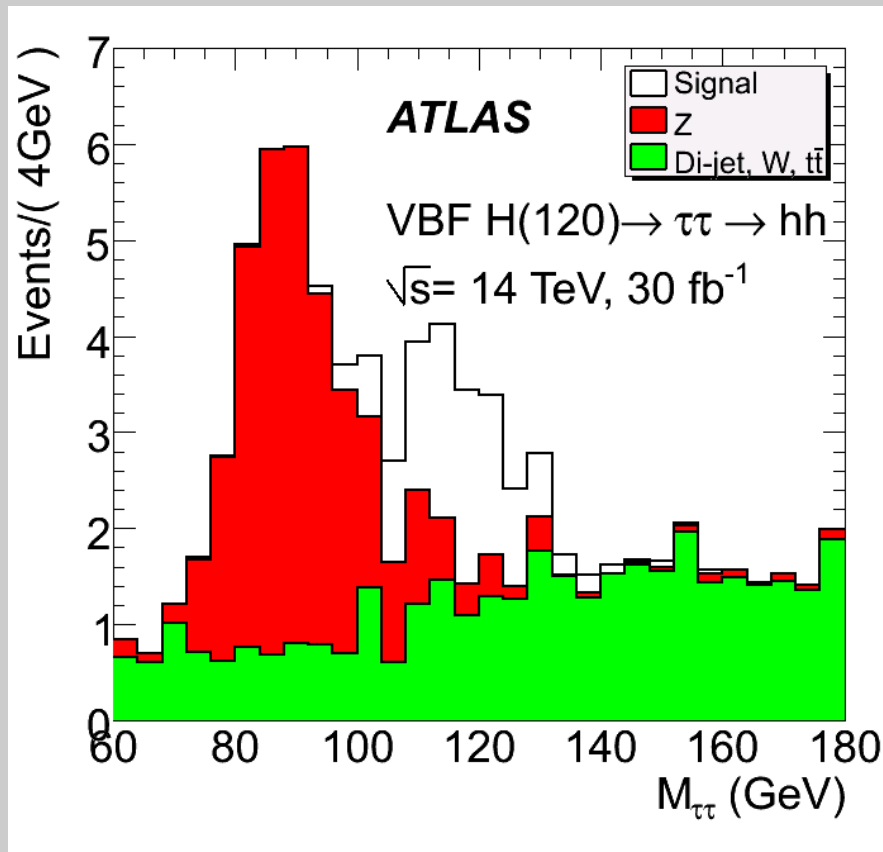
→ Heavy mass channel

$gg/gb \rightarrow tH \rightarrow ttb \rightarrow$
 $\boxed{b} \boxed{l\nu} \boxed{bqqb}$
 $gg/gb \rightarrow tH \rightarrow$
 $\boxed{bqq} \boxed{\tau(\text{had})\nu}$





Tau trigger in neutral Higgs searches



- SM $H \rightarrow \tau\tau$ (VBF)
 - Study of all lepton, lepton-hadron and all hadron channels
 - Efficiency in all hadron channels comparable with other channels but sensitivity of QCD background to be studied with data.

(The A/H $\rightarrow \tau\tau$ study didn't use tau trigger at the time of CSC)

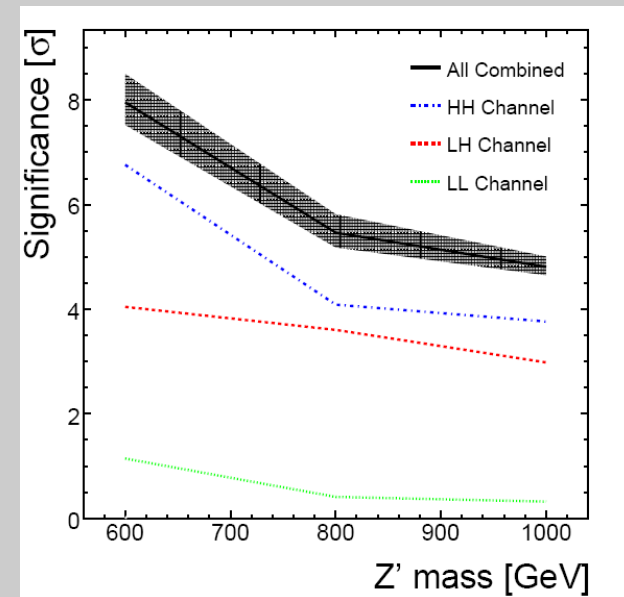
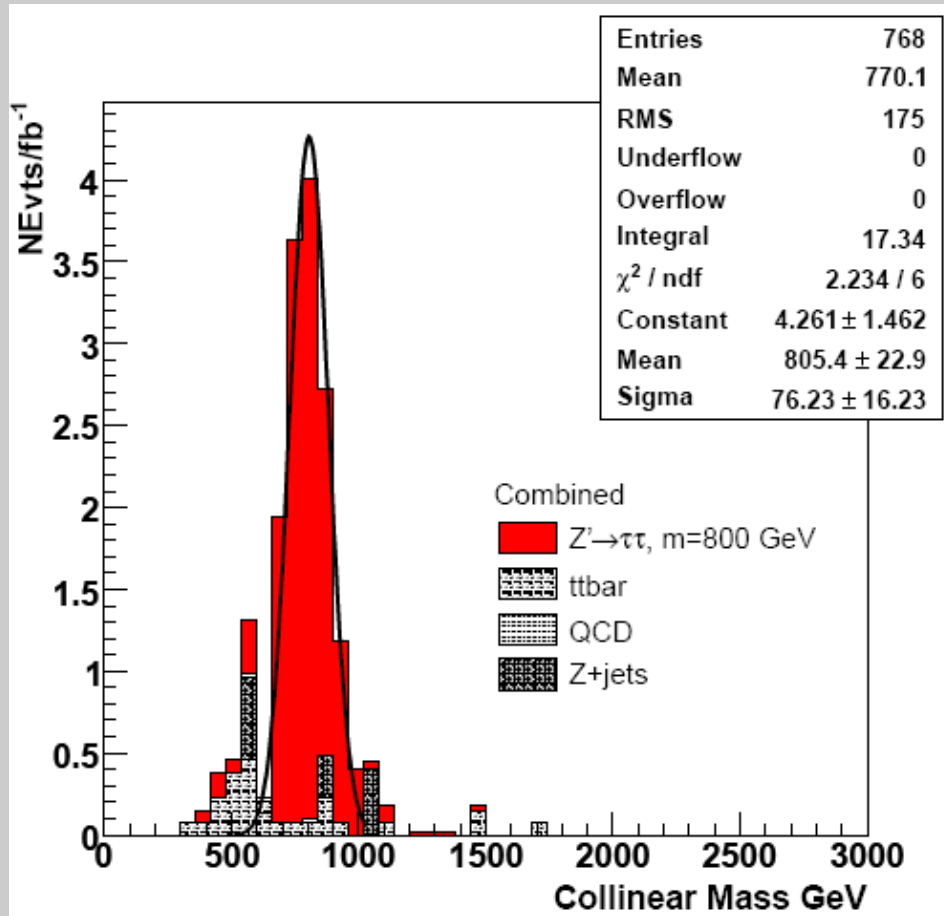


And trigger for exotics?

- Heavy vector bosons:

$$Z' \rightarrow \tau\tau$$

- double tau lepton final states.
- discovery is enhanced including all hadron final states.



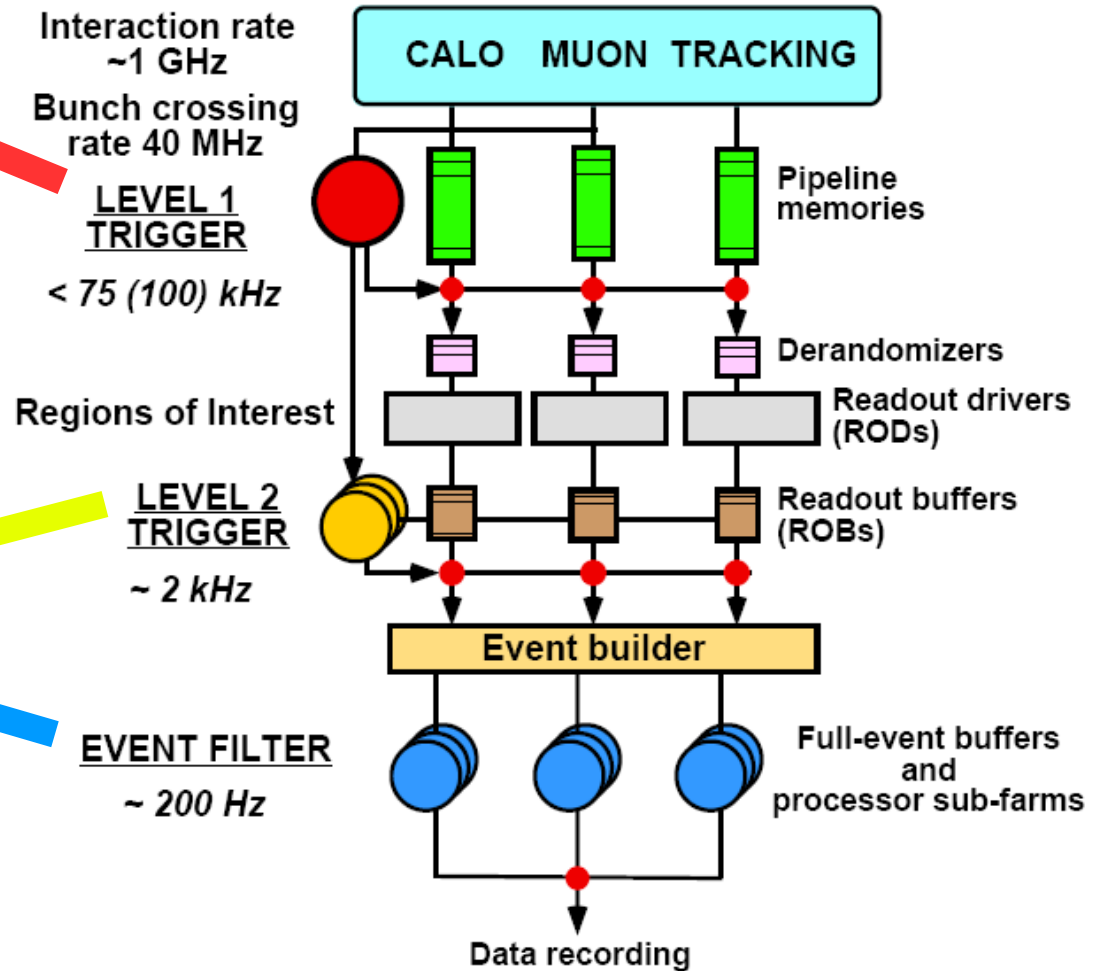
ATLAS trigger chain



LVL1 trigger in USA15 counting room underground

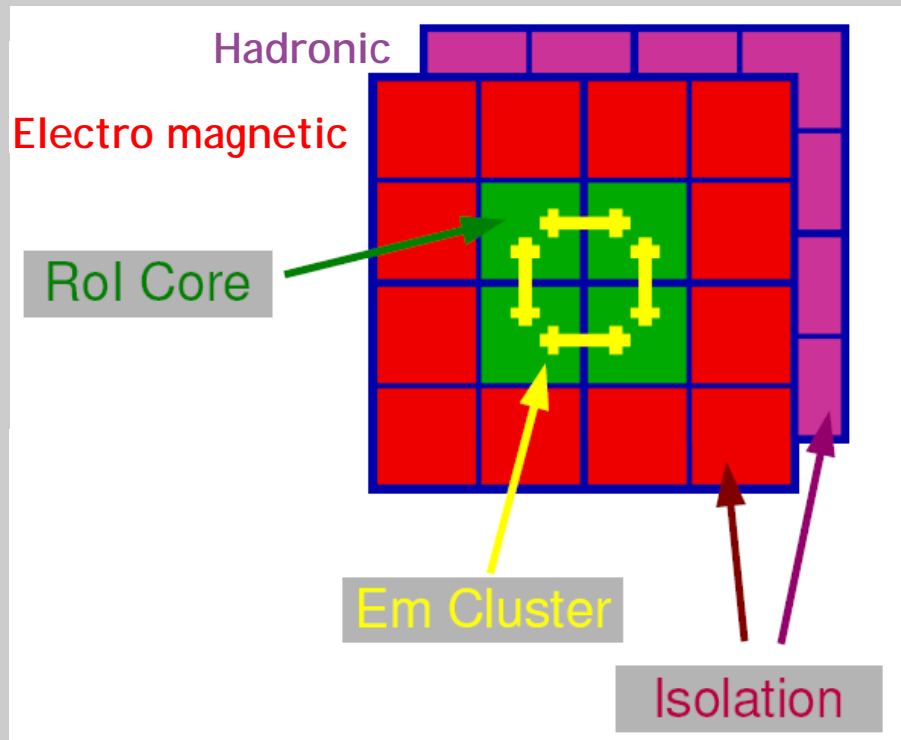


High Level trigger in surface building SDX1



LVL1 trigger quantities

$$\Delta\eta \times \Delta\phi = 0.1 \times 0.1$$

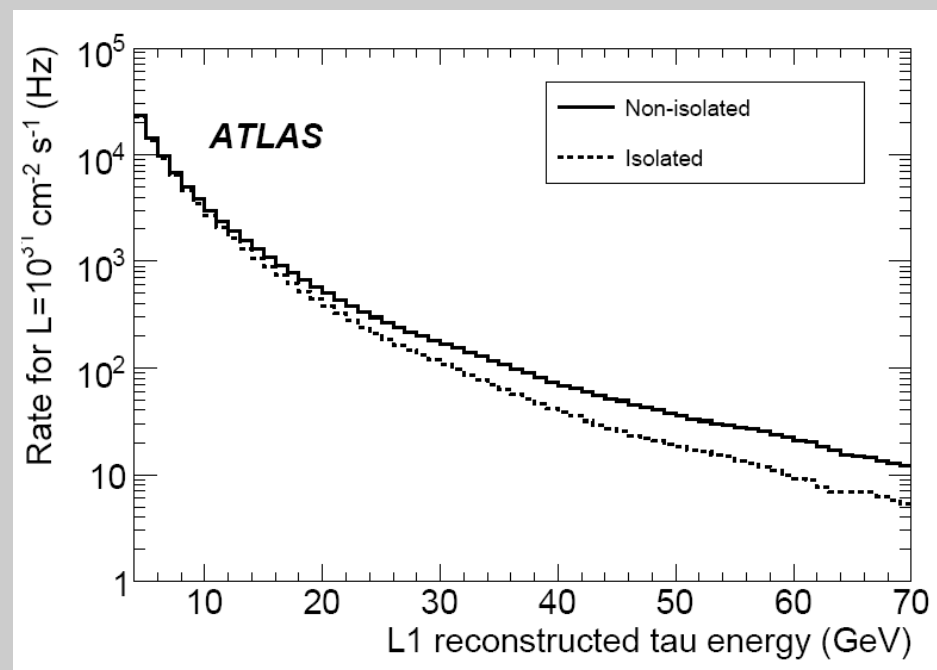
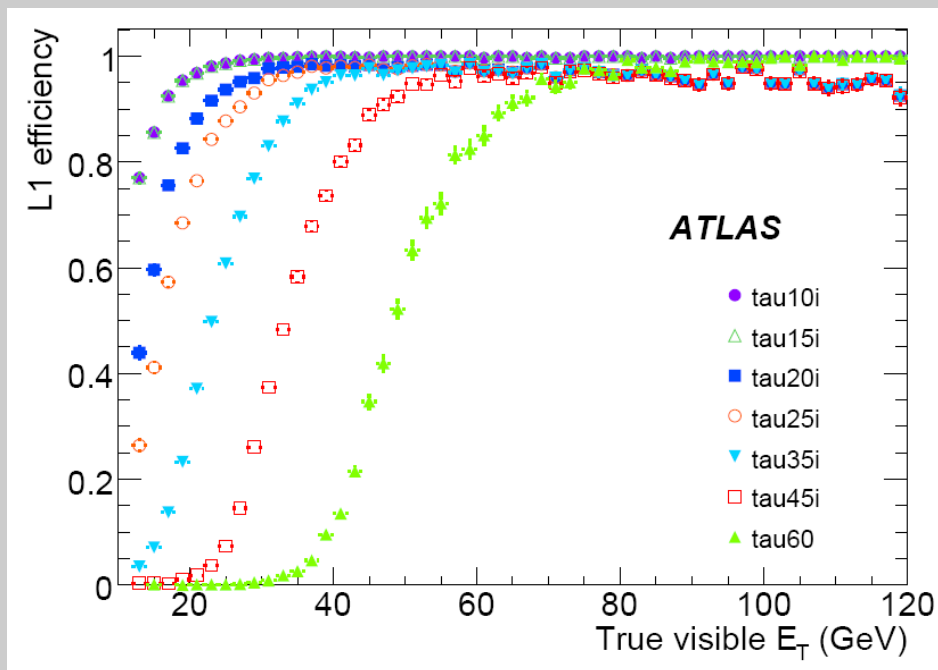


Coverage $|\eta| < 2.5$

- Central 2x2 core of both e.m. and hadronic towers
- Tau cluster=two most energetic neighboring e.m towers+ central 2x2 hadronic towers
- EmIsol=energy in the isolating ring 2x2 to 4x4 in e.m. calorimeter
- HadIsol=energy in the isolating ring 2x2 to 4x4 in hadronic calorimeter

Maximum 8 trigger thresholds

LVL1 trigger performance for single taus



Tau efficiency $|\eta| \leq 2.5$

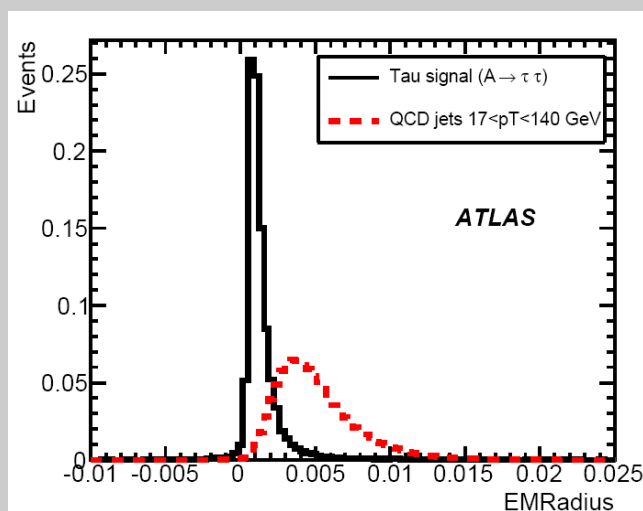
$$\mathcal{L} = 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$$

(Dijet sample $8 < p_T < 140 \text{ GeV}$)

HLT-L2 & EF

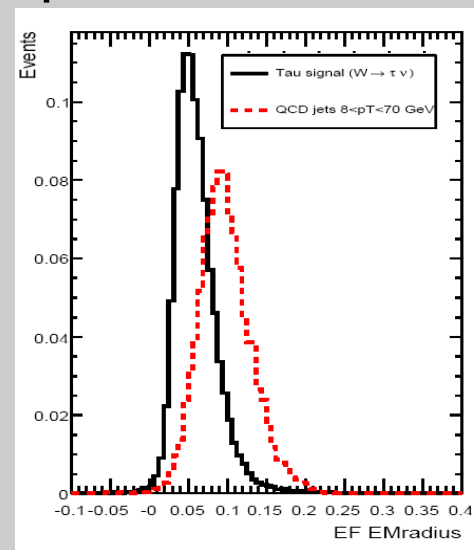
- Seeding ROI form L1

- First, search for taus in calorimeter
- Second, for taus in tracker
- Extracted tau variables are shape variables

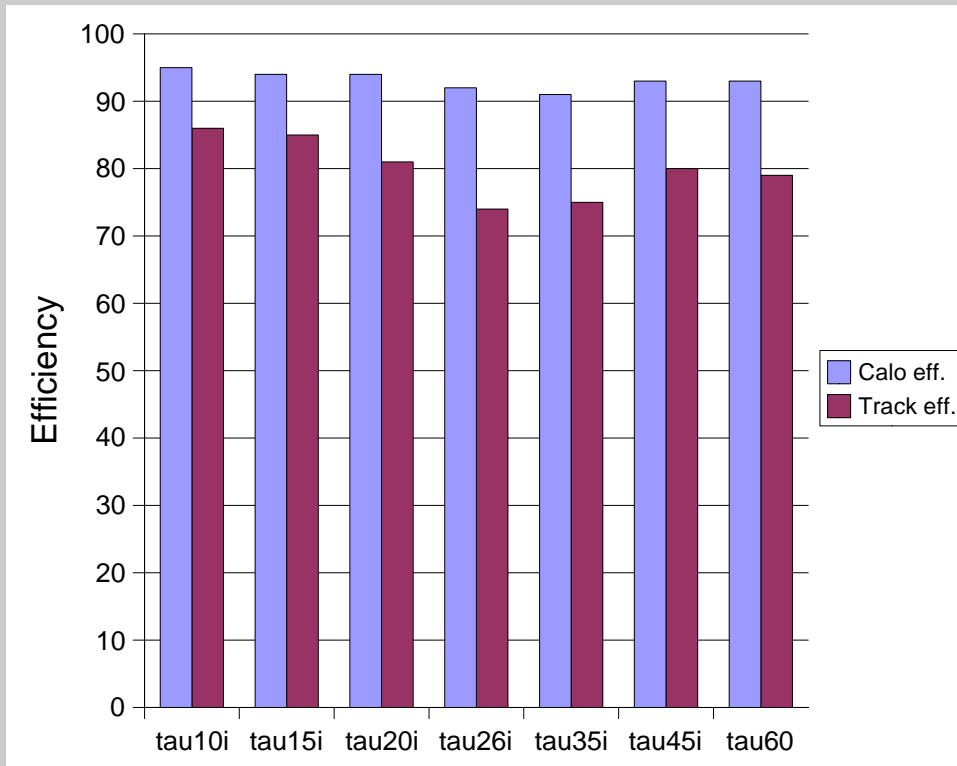


- Seeding from L2

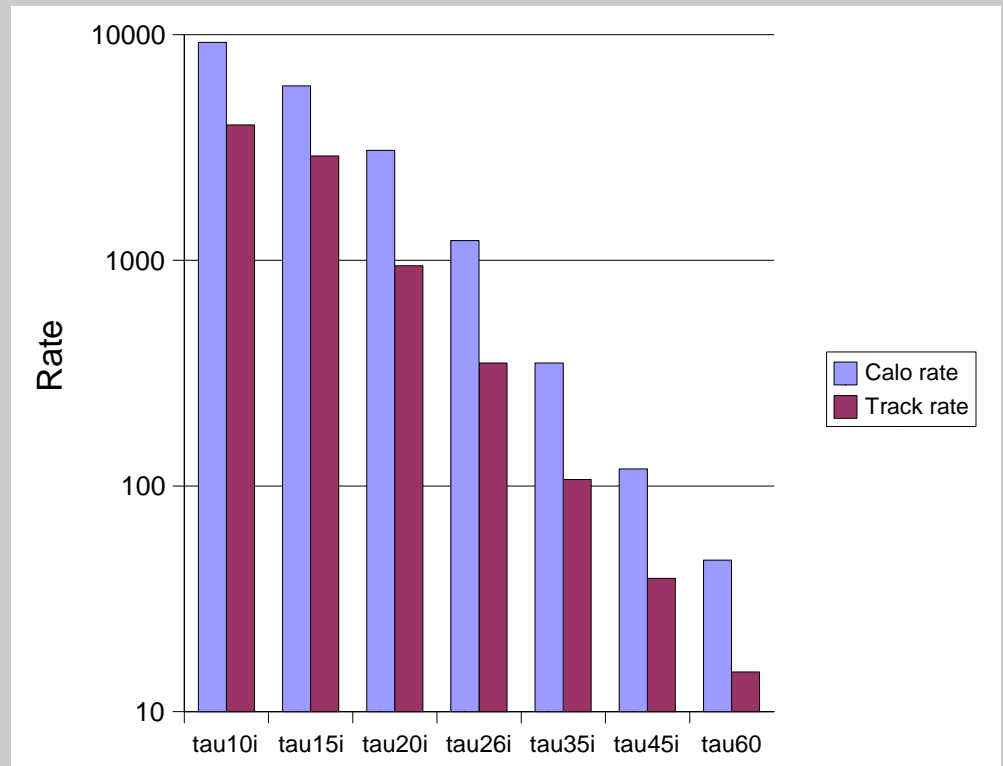
- EF is repeating the LVL2 steps but in a much more sophisticated tau identification algorithm taken from offline.
- Shape variables extracted



LVL2 trigger performance for single taus

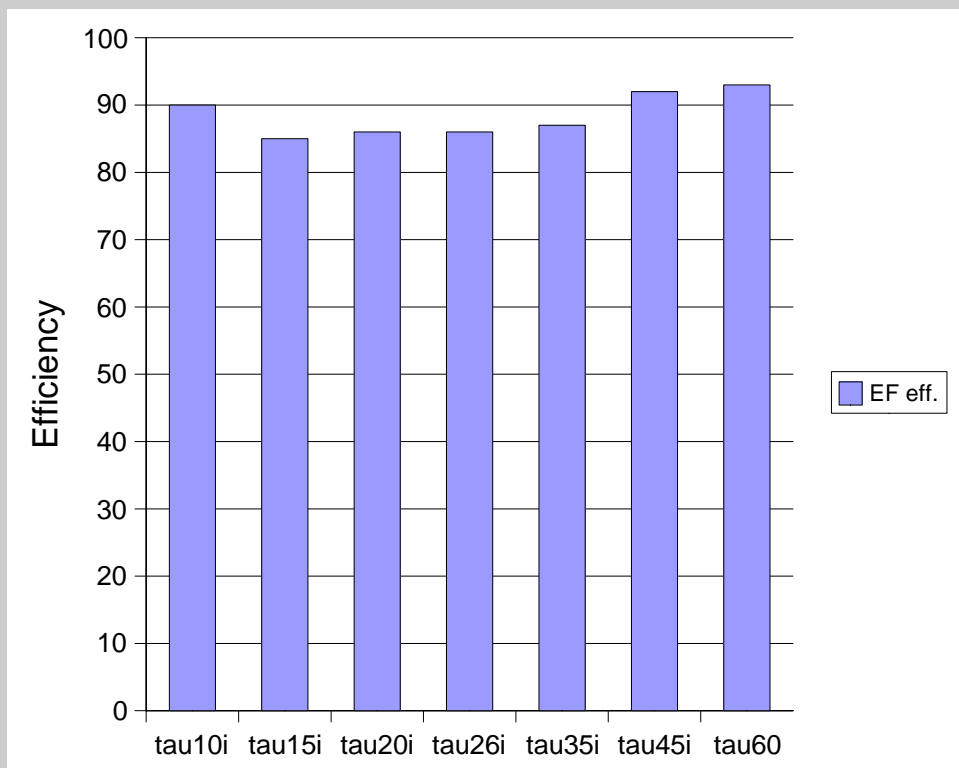


Efficiency for $W \rightarrow \tau \nu$

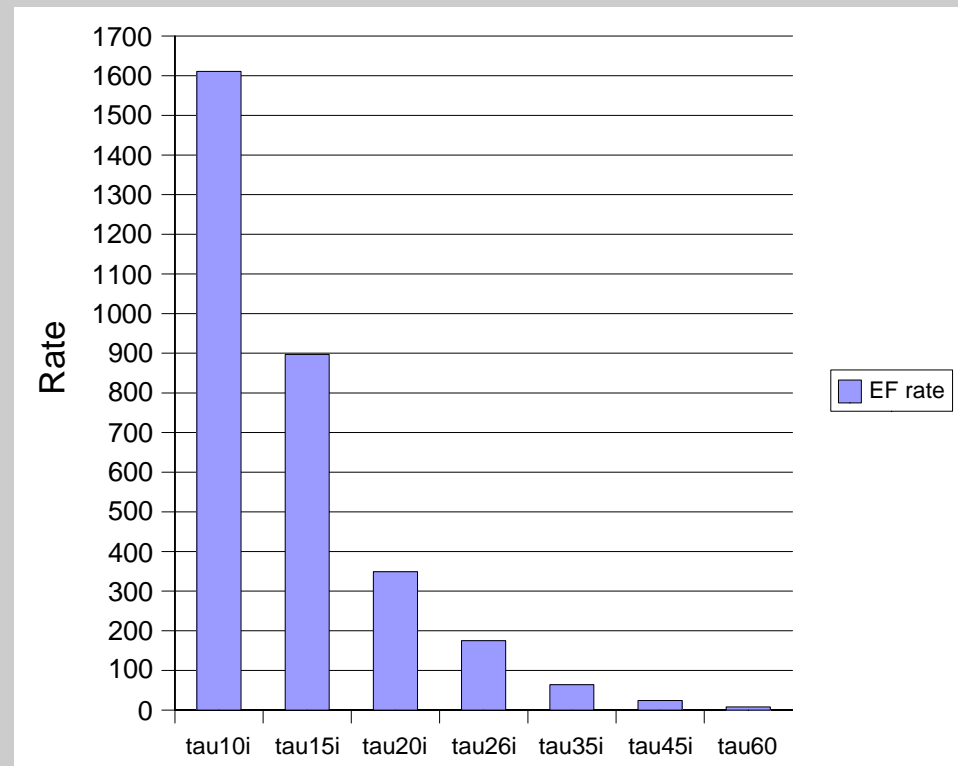


QCD rate at $L=10^{31} \text{ cm}^{-2} \text{ s}^{-1}$

Event Filter performance for single taus



Efficiency for $W \rightarrow \tau \nu$



QCD rate at $L=10^{31} \text{ cm}^{-2} \text{ s}^{-1}$

Tau trigger items

- Tau only
 - Single tau: apart from very high E_T these triggers are to be used in combination with other triggers.
 - Single track trigger: select Rol:s with only 1 track. Run parasitic without L1 trigger item.
- Combined triggers
 - tau+missing E_T : For W decays and similar (H^\pm)
 - $L=10^{31}$: XE30_L1_TAU13, XE20_3j20_L1_TAU13
 - $L=10^{31}$: XE40_3j20_L1_TAU30, XE50_L1_TAU30
 - tau+l(+jets): Optimized for double tau decays (Z,H/A,...)
 - L1_TAU30_XE40_softHLT
 - tau+tau(+jets): Like previous but all hadronic
 - tau+jets,tau+bjets: Option for tt -studies allowing lower threshold
 - Commissioning: Only a fraction will be recorded.

Tau trigger menu at start-up

$L=10^{31} \text{ cm}^{-2}\text{s}^{-1}$

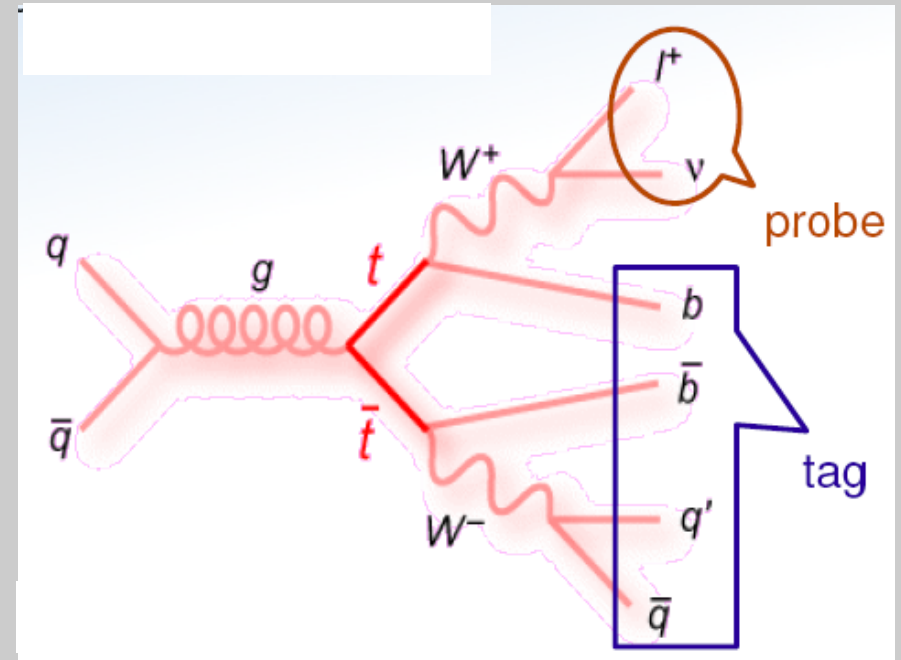
Trigger	Prescale	Rate (Hz)	Cumulative Rate (Hz)
tau100	1	2.4 ± 0.5	2.4 ± 0.5
tau60	1	10.7 ± 1.0	10.7 ± 1.0
tau45i	10	2.5 ± 0.2	12.6 ± 1.1
tau45	20	4.1 ± 0.1	16.0 ± 1.4
tau20i_xe30	1	4.9 ± 0.7	20.1 ± 1.4
tau20i_e10	1	1.2 ± 0.4	21.2 ± 1.5
tau20i_mu6	1	2.8 ± 0.5	23.7 ± 1.6
2tau25i	1	2.6 ± 0.5	25.3 ± 1.6
tau20i_4j23	1	0.1 ± 0.1	25.4 ± 1.6
tau20i_3j23	1	0.9 ± 0.3	25.8 ± 1.6
tau20i_j70	1	7.1 ± 0.9	28.6 ± 1.7

Note: The naming convention for menus have changed to effective threshold levels e.g. tau20 -> tau17

Commissioning of tau trigger with first data (studies in progress)

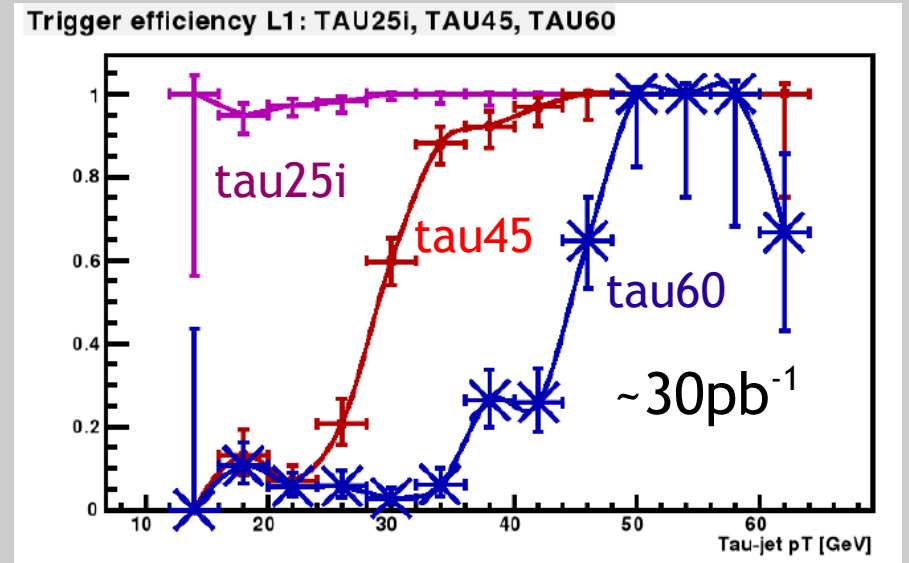
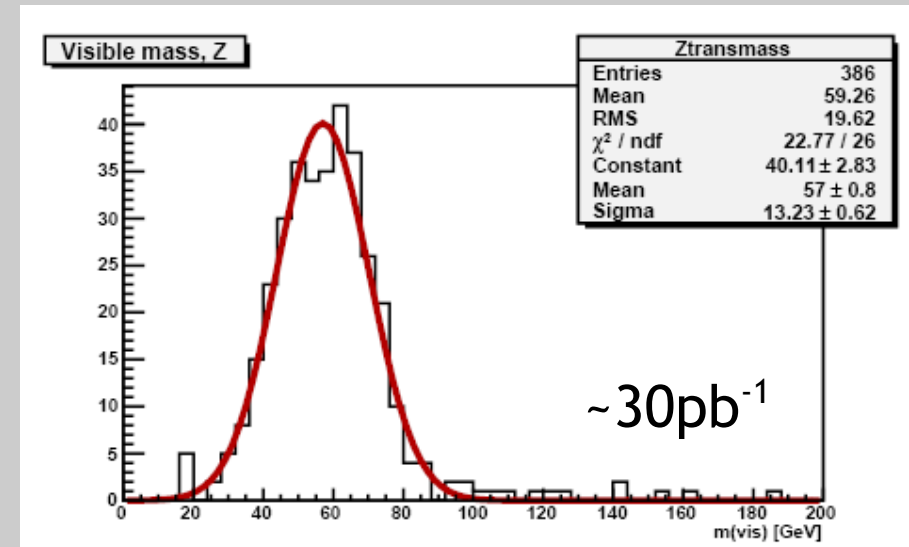
- Efficiency of Tau+XET with $t\bar{t}$ events

- tag: 4jet25
- make offline selection and probe
- main background: QCD, single top
- $t\bar{t}$ samples with an estimated background of 35% in the tagged sample
- 3% statistical uncertainty for tau25i_xe20 with 100 pb^{-1} data



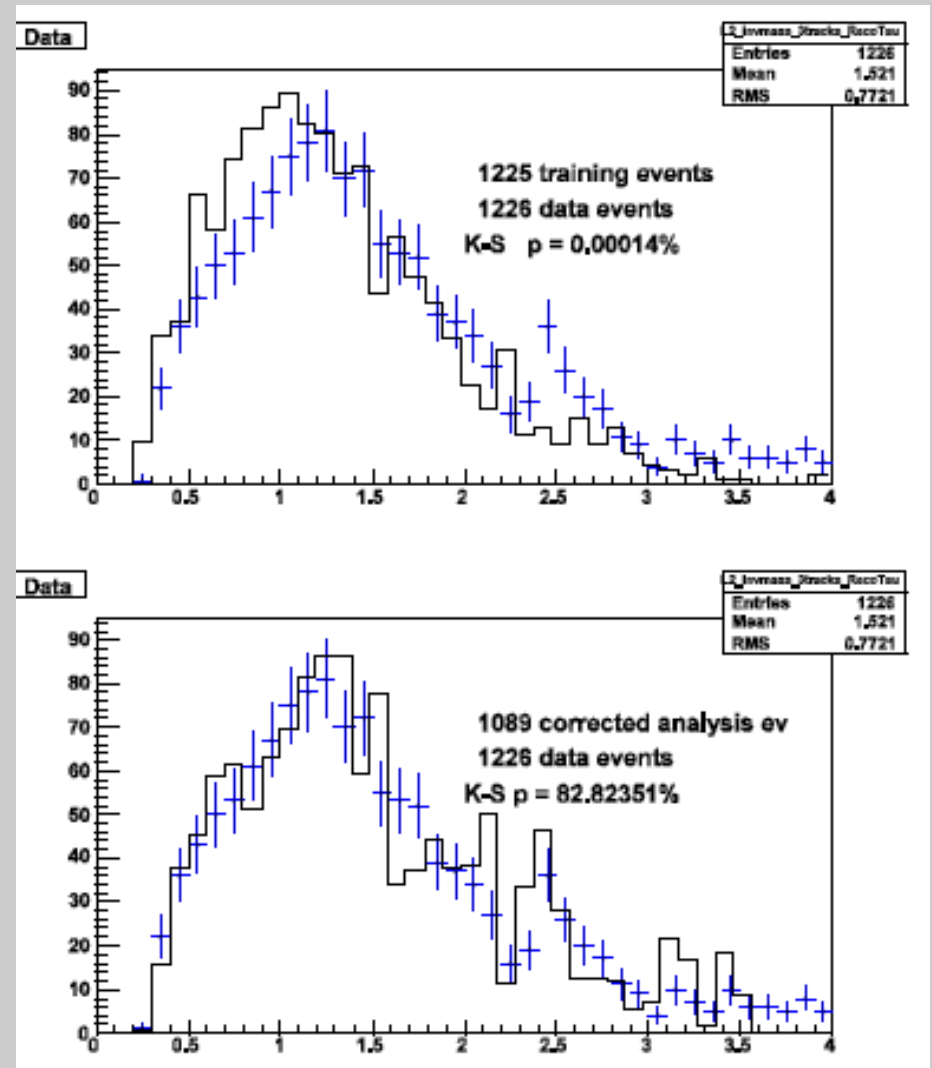


- Efficiency and turn-on curves with $Z \rightarrow \tau\tau$
 - Tag: e or μ
 - Reconstruct Z offline, study $\tau \rightarrow \text{had}$
 - Background dominated by top and QCD
 - Expect ~ 1200 signal events in 100pb^{-1} with 30% background
 - First single tau trigger turn-on curves can be made.





- Tuning of trigger variables with data
 - Develop methods for using data to correct single shape variables
 1. MC training sample vs. data -> correction parameters extracted
 2. MC with corrections (analysis sample) then used on data
 - Develop methods to get the MC contents to look like data, especially important to understand backgrounds





Conclusions

- A full set of single tau and combined tau triggers has been defined for start-up of LHC
- Low threshold tau triggers need to be combined with other triggers to keep trigger rates low while high threshold trigger can be used as single tau triggers.
- Tau triggers has been used in the CSC work and the use of tau trigger menus are expected to increase in the future
- Tau trigger performance will be measured and tuned with first data.

Conclusions

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- Tau triggers has been used in the CSC work and the use of tau trigger menus are expected to increase in the future
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...may be as soon as this week-end when we expect first collisions



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Back-up slides



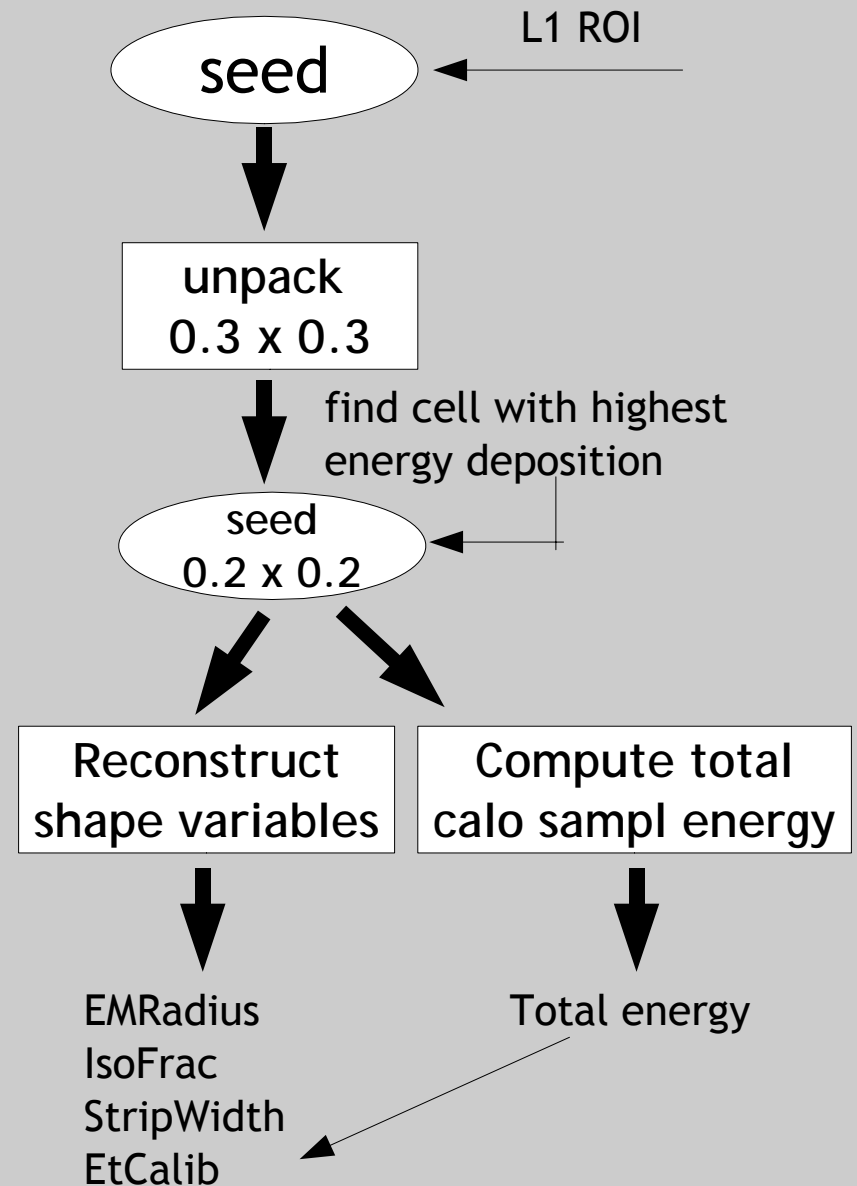
LVL2 trigger- calorimeter variables

- EMRadius: calculated in a window around the seed

$$EMRadius = \frac{\sum_{0.3 \times 0.3} E_{cell} \cdot R_{cell}^2}{\sum_{0.3 \times 0.3} E_{cell}}$$

- IsoFrac: Normalised difference in the energy between a 0.1x0.1 and 0.2x0.2 window

$$IsoFrac = \frac{\sum_{0.2 \times 0.2} E_{cell} - \sum_{0.1 \times 0.1} E_{cell}}{\sum_{0.2 \times 0.2} E_{cell}}$$

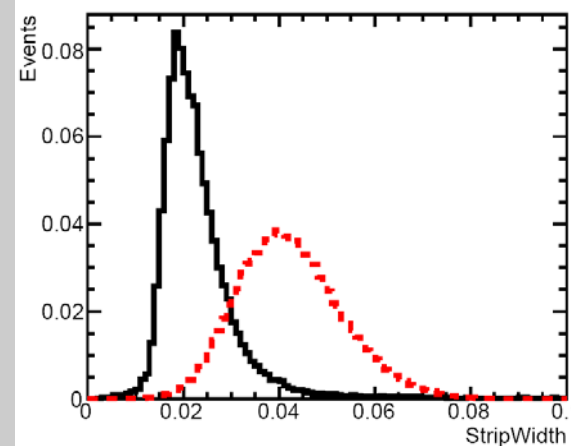
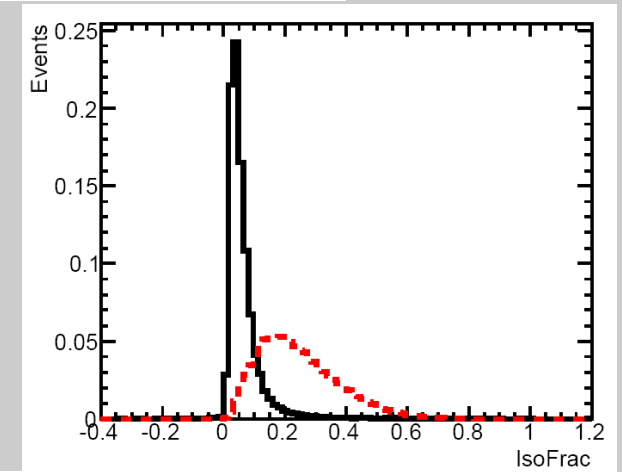
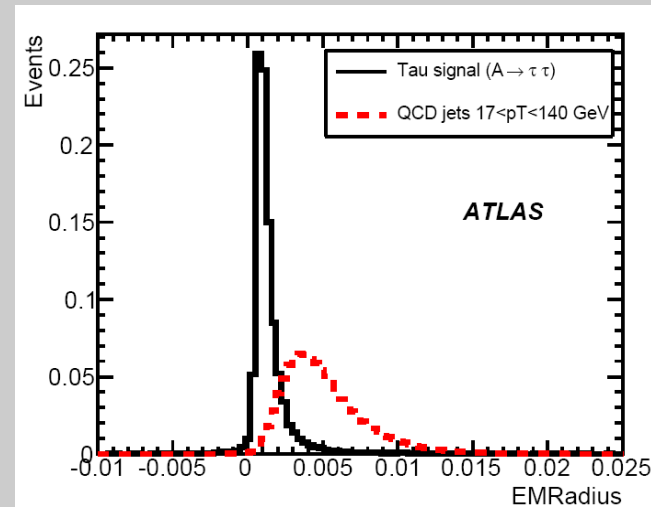




- StripWidth: Energy weighted width of the energy deposition in η

$$IsoFrac = \sqrt{\frac{\sum_{0.3 \times 0.3} \eta_{cell}^2 \cdot E_{cell}}{\sum_{0.3 \times 0.3} E_{cell}} - \left[\frac{\sum_{0.3 \times 0.3} \eta_{cell} E_{cell}}{\sum_{0.3 \times 0.3} E_{cell}} \right]^2}$$

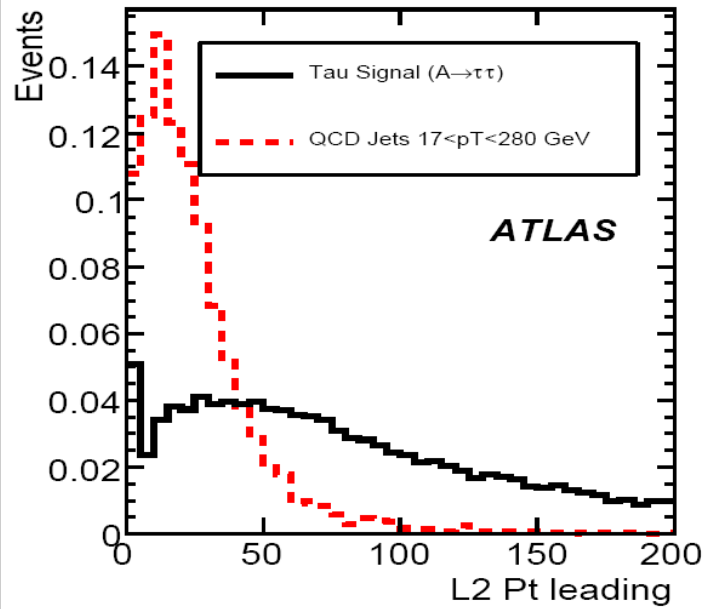
- EtCalib: Total transverse momentum in both e.m. and hadronic calorimeters in 0.3×0.3 window



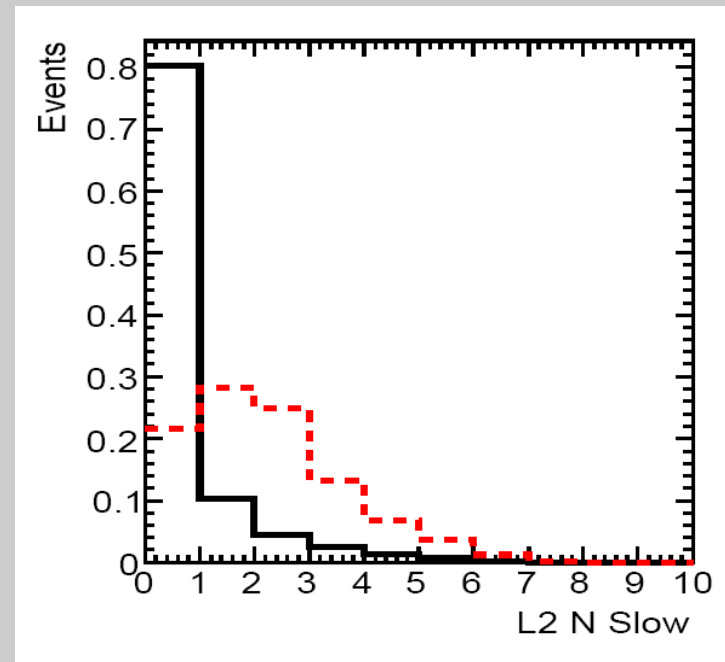
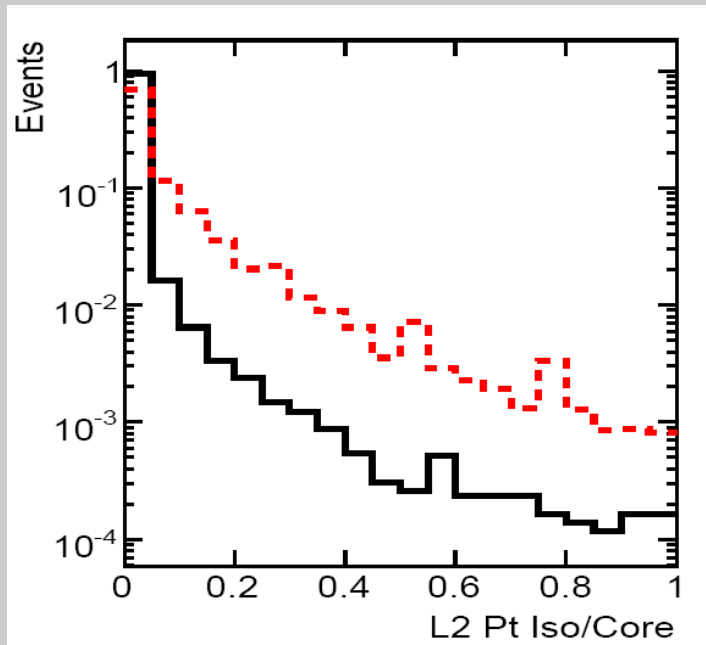
$$m_A = 800 \text{ GeV}$$

LVL2 trigger-tracking variables

- The LVL2 track trigger is run after the calorimeter
- Tracks with $p_T > 1.5 \text{ GeV}$ in 0.6×0.6 region around calorimeter seed (TRT not included)
- RoI around highest p_T track 0.15 (core) and 0.3 (nor)
- Isolation ring between 0.15 and 0.3
- ➔ Pt leading: Highest $p_{T\text{track}}$
- ➔ Pt Iso/Core: ratio of scalar sum of track p_T in core and isolation regions
- ➔ N Slow tracks: Number of tracks in the core region with p_T below a threshold (e.g. $7.5 \text{ GeV}/c$)
- ➔ Charge: Sum of charges of tracks in nor region
- ➔ N Tracks: total number of tracks in nor region



$$m_A = 800 \text{ GeV}$$



Event Filter variables

- EF is repeating the LVL2 steps but in a much more sophisticated tau identification algorithm taken from offline.
- The seeding is taken from LVL2
- Main variables are: EMRadius, IsoFrac, N Tracks, Pt leading track and EtCalib.

